AMENDED SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in or relating to Aluminium Silicon Alloys

I, HAROLD GEORGE CRUIKSHANK FAIRWEATHER, of 29, Southampton Buildings, Chancery Lane, London, W.C.2, of British Nationality, do hereby declare the nature of this invention (a communication from The National Smelting Company, a corporation organized and existing under the laws of the State of Ohio, United States of America, of 6700, Grant Avenue, Cleveland, State of Ohio, United States of America), and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to aluminium-silicon alloys suitable for making castings having relatively high strength and ductility.

Aluminium-silicon alloys having relatively high strength and hardness, and having relatively high elongation, are very desirable for many applications, such as for pistons, parts of internal combustion engines.

Aluminium-silicon alloys containing other alloying ingredients have frequently been used in the production of pistons and internal combustion engine parts. In such alloys, when the proportion of silicon is increased the thermal expansion of the alloy is decreased, and the hardness and wear resistance of the alloy are increased. Frequently, however, such alloys although they have relatively great wear-resistance do not have a sufficient degree of ductility.

It is an object of the present invention to provide an aluminium-silicon alloy having improved wear-resistance, good machinability and increased elongation.

In accordance with the present invention, these objects are accomplished by an alloy consisting of 3% to 13% silicon, .1% to 2% magnesium, .1% to 1.5% manganese, .05% to 1.5% chromium, .1 to 1.5% zinc, 0.5% to 4% copper, up to 1.8% iron, one or more grain refiners in a total amount of from .002 to .5% selected from the group consisting of .05% to .3% titanium, .01 to 0.3% niobium, .01 to .3% zirconium, .002 to .1% boron, .01 to .3% tungsten, .01 to .3% molybdenum, and .05 to .3% vanadium, and the remainder aluminium.

It is recognized that manganese has been used in aluminium-silicon alloys to add strength and hardness and that chromium has been used in certain alloys as a hardener. The advantages of the use of both manganese and chromium in an aluminium-silicon alloy however have not heretofore been known as far as we are aware. Since both manganese and chromium are hardening elements, one would ordinarily expect the addition of both of these ingredients to increase the hardness and brittleness of the aluminium-silicon alloy. Contrary to such expectations, I have found that the simultaneous use in alloys of the present invention of both manganese and chromium increases the ductility of the alloy without substantial change in tensile strength, so that while the long-wearing characteristics of an aluminium-silicon alloy is retained, the alloy is capable of withstanding greater shocks and is less liable to fracture.

The amount of silicon present in the alloy depends on the particular industrial application to which the alloy is to be put. As is well-known, there is a series of aluminium-silicon alloys suitable for high-strength castings, such as

cylinder blocks, crankcases, bearing blocks, cylinder heads, or marine castings, where high strength and ductility are desirable, and which contain from 2% or 3% to 8% or 9% silicon. In the alloy according to the invention, silicon is present in an amount from 3% to 13%, preferably 3% to 9%.

There are also aluminium-silicon alloys containing 8% or 9% to 12% or 13% of silicon, and having relatively high strength, in which this higher range of silicon increases the fluidity of the casting metal and tends to decrease shrinkage porosity. These alloys are frequently used in the casting of pistons, pressure vessels, parts of hydraulic brakes and the like.

Magnesium is desirable in aluminium-silicon alloys for the reason that it combines with sufficient of the silicon to form magnesium silicide, an effective hardening agent which increases the strength and hardness of the alloy, improves its machinability, but tends to reduce its ductility. Magnesium may be present in the alloy of the present invention in amount from .1% to 2%, but preferably it is present in an amount of .2% to .8% or 1%. Particularly when good ductility is desired, it is preferable to have the magnesium below .7%, for instance .65%.

Manganese, as is recognized by those skilled in the art, has the property of inhibiting grain growth at elevated temperatures. It thus makes aluminium alloys more adaptable for use in production of castings or other motor parts which are to be subjected to heat for long periods of time.

In aluminium-silicon alloys containing iron and titanium, relatively large needle-like iron crystals, crystals of aluminium-iron-silicon complex, and/or crystals of an aluminium-silicon-iron-titanium complex tend to form. However, when manganese is present the iron, silicon and titanium constituents tend to be more finely dispersed. Manganese improves the tensile strength, yield strength and proportional limit of aluminium-silicon alloys containing iron, and when present in the proper proportion it may also increase the elongation of the alloy. An increase in elongation is particularly noticeable, however, when chromium is also present as hereinafter set forth.

Chromium is generally considered to be a hardener and would, therefore, normally be expected to decrease ductility. It has been discovered, however, in accordance with the present invention, that in aluminium-silicon alloys chromium in conjunction with manganese markedly increases ductility of the alloy without substantially impairing the strength and hardness. This is especially noticeable in alloys subjected to heat treatments.

The combination of manganese and chromium, however, is not so advantageous for aluminium-silicon alloys when sufficient silicon, namely 12% to 13%, is present to reduce the ductility of the alloy to 1% or less.

Iron may be present in the alloy of the present invention up to 1.3%, although it is preferred to have the iron content below .7 or .8%.

The manganese is present in an amount from .1% to 1.5%, but preferably is not over .7% or .8%. It is desirable to have the total of manganese and iron present in an amount not over 2%, but if the iron content of the alloy is relatively high, such as in the neighborhood of 1%, it is preferable to have the manganese content relatively low, such as from .25% to .5% or .6%.

Noticeable benefits are obtained in the present invention when chromium is present in amounts as low as .05% to .1% although much more desirable results are had when .1% to .5% or .6% of chromium is present. When the amount of chromium is increased to 1% or 1.5% the proportionate improvements are usually somewhat less.

Copper is present in an amount from 0.5 to 4%. Copper in amounts from about 0.5% to 4%, while having a tendency to reduce the ductility of the alloys, tends to increase the yield strength and resistance to fatigue, as well as substantially improving machinability of the alloys. Copper improves the properties due to heat treatment noticeably. The preferred amount of copper for most purposes usually runs from 0.5% to 2% or 3%.

With both manganese and chromium present in the aluminium-silicon alloys of the invention the benefits of larger amounts of copper can be obtained without too greatly decreasing the ductility of the alloy.

The desirable effects of the combination of manganese and chromium are had in alloys of the present invention when the silicon content is as low as 3%. The commercial applications normally filled by the lower silicon alloys, i.e., those alloys having a silicon content of from 3% to 6% may be filled with the alloys of the present invention with a somewhat larger silicon content, such as 7% to 9%.

The alloys comprehended by this in-

vention may have their properties still further improved by well-known modification processes utilizing alkali metals such as metallic sodium or potassium, or one or more of their fluorides.

One or more of the grain refining elements selected from the group consisting of titanium, niobium, zirconium, boron, tungsten, vanadium and molybdenum are added to the alloy, in a total amount of from .002% to .5%.

When used singly or in combination, titanium may be present in the amount of .05% to .3%; niobium in amount of .01% to .3%; zirconium in amount of .01% to .3%; boron in amount of .002% to .1%; and tungsten in amount of .01% to .3%; vanadium in amount of .05% to .3%; and molybdenum in amount of .01% to .3%.

An alloy containing 6% silicon, .25% magnesium, 1.4% copper, .7% iron, .25% manganese, .1% titanium, .2% zinc and the remainder aluminium, was made up with no chromium, and also with the chromium additions shown in the following table. The various alloys were sand-cast into test bars, which were heat treated at about 960° F. for 12 hours, quenched in hot water, and aged 2 hours at 212° F. The various test bars had the properties given below:

Cr. %	Prop. Limit p.s.i.	Yield Strength p.s.i.	Tensile Strength p.s.i.	Elong. %	Hardness Rockwell "E"
0	11,500	20,800	30,500	2.0	74.7
.1	12,400	20,300	29,100	2.2	73.4
.2	12,000	19,600	31,100	3.3	72.7
.25	11,600	19,000	30,300	3.4	69.2
.3	10,500	17,900	32,300	4.3	70.8
.5	11,700	17,900	30,400	3.8	68.4

The alloy of the above example with .2% chromium was sand-cast, heat treated at 960° F. for about 12 hours, quenched in hot water, and aged at about 300° F. for 5 hours. It had a proportional limit of 22,200 lbs./sq. in., a yield strength of 31,400 lbs./sq. in., a tensile strength of 40,600 lbs./sq. in., an elongation of 2.1%, and a hardness of 87 Rockwell E.

When the same alloy was given the sodium modification treatment, sand-cast, and given the same heat treatment as above, it had a proportional limit of 21,600 lbs./sq. in., a yield strength of 30,600 lbs./sq. in., a tensile strength of 38,800 lbs./sq. in., an elongation of 2.7% and a hardness of 86 Rockwell E.

An alloy containing 7.5% silicon, 1% copper, .3% magnesium, .3% manganese, .1% titanium, .6% iron, .2% zinc and the remainder aluminium, was made up with no chromium, and with additions of about .2% chromium and about .3% chromium, respectively. The various alloys were sand-cast into test bars, some of which were heat treated at about 960° F. for 12 hours, quenched in hot water, and aged at room temperature for three days. These test bars had the properties given below:

Cr. %	Prop. Limit p.s.i.	Yield Strength p.s.i.	Tensile Strength p.s.i.	Elong. %	Hardness Rockwell "E"
0	10,300	19,000	31,600	2.4	77.2
.2	9,800	17,700	33,400	3.8	75.3
.3	10,300	17,800	33,500	3.9	77.2

Some of the same test bars were heat treated at 960° F. for 12 hours, quenched in hot water, and aged for four hours at about 300° F., with the following results:

Cr. %	Prop. Limit p.s.i.	Yield Strength p.s.i.	Tensile Strength p.s.i.	Elong. %	Hardness Rockwell "E"
0	18,800	29,300	37,400	1.0	87.2
.2	18,200	27,900	38,100	2.0	84.8
.3	19,100	28,200	39,200	2.1	87.0

The presence of a small amount of zinc improves the machinability of the alloy without impairing the properties of the alloy. It is therefore desirable to have zinc present in an amount from .1% or .2% to about 1% or even 1.5%. Very noticeable improvement in the machinability is obtained with .2% or .3% or so of zinc in the aluminium alloys of this invention.

If it is desired to improve the machinability and the thermal conductivity of the alloy, tin may be present in an amount up to 1%.

It will be seen that the increased ductility obtainable in the alloys of the present invention, as compared with similar aluminium-silicon alloys not containing both manganese and chromium, makes it possible to use aluminium-silicon alloys with a higher silicon content to meet the requirements of commercial applications normally filled only by those with lower silicon, and thus to use an alloy having a decreased coefficient of thermal expansion due to the presence of more silicon.

Having now particularly described and ascertained the nature of my said invention (as communicated to me by my foreign correspondents), and in what manner the same is to be performed, I declare that what I claim is:—

1. An aluminium-silicon alloy consisting of 3% to 13% silicon, .1% to 2% magnesium, .1% to 1.5% manganese, .05% to 1.5% chromium, .1 to 1.5% zinc, 0.5% to 4% copper, up to 1.3% iron, one or more grain refiners in a total amount of from .002 to .5% selected from the group consisting of .05 to .3% titanium, .01 to .3% niobium, .01 to .3% zirconium, .002 to .1% boron, .01 to .3% tungsten, .01 to .3% molybdenum, and .05 to .3% vanadium, and the remainder aluminium.

2. An alloy according to claim 1 containing 0.5 to 3% copper.

3. An alloy according to claim 1 or 2 containing 3% to 9% silicon.

4. An alloy according to claim 1, 2 or 3, in which the total amount of manganese and iron present does not exceed 2%.

5. An alloy according to any of the preceding claims, including up to 1% tin.

6. An aluminium silicon alloy as hereinbefore described with reference to the Examples which include chromium.

Dated this 1st day of December, 1945.

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